



## Original Communication

## Sternal index: Is it a reliable indicator of sex in the Maharashtra population of India?

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## ABSTRACT

Sex determination is an important initial step in forensic investigation of unknown human skeletal remains. The present analysis is an attempt to determine the sex of the sternum using sternal index as a parameter in a Maharashtra population of India. Sternal index is calculated in 115 adult sternums of confirmed sex (75 male and 40 female) for sexual dimorphism. The sternal index is derived by dividing the length of manubrium by the length of mesosternum and multiplying it by 100. Although the sternal index is found to be significantly higher in females, the analysis suggests that sex determination cannot be made conclusively from the sternal index in the Maharashtra region of western India. The study further concludes that the applicability of Hyrtl's law in sex determination is limited.

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## 1. Introduction

Sex determination is an important preliminary lead in forensic investigations of unidentified human skeletal remains. While commenting on human skeletal sexual dimorphism, Gray's anatomy quotes "Anatomists, anthropologists, and forensic scientists have long judged the sex of skeletal material by non-metrical observations. More recently, sexual divergence has been based upon measurements in many different bones. Such studies emphasize the need for standards of sexual dimorphism in different populations".<sup>1</sup>

Sexual dimorphism in human sternum was first noted by Wenzel,<sup>2</sup> who observed that although manubrium of the two sexes is of almost equal length, the mesosternum is proportionately longer in males than in females. This led to pronouncement of Hyrtl's law<sup>3</sup> that "the manubrium of the female sternum exceeds half the length of the body, while the body in the male sternum is, at least, twice as long as the manubrium".

Determination of sex of the sternum by the length of manubrium, length of mesosternum, and the combined length of manubrium and mesosternum in the Maharashtra population of western India has been reported previously.<sup>4</sup> The present analysis is a supplement to the previous report<sup>4</sup> on sexual dimorphism of the sternum in the Maharashtra population of India. The present analysis attempts to evaluate whether the sternal index is useful for sexing the sternum in the Maharashtra region of western India. The applicability of Hyrtl's law in sex determination in the Maharashtra population is also tested.

## 2. Materials and methods

One hundred and fifteen adult human dried sternums from cadavers dissected between 1998 and 2002 were obtained from Government Medical Colleges of Miraj, Sholapur, Aurangabad and Kolhapur in Maharashtra. Maharashtra located in western India is India's third largest state in area and second largest in population.<sup>5</sup> The sample was the same used for determination of sex of the sternum by the length of manubrium, length of mesosternum,

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and the combined length of manubrium and mesosternum.<sup>4</sup> The cadavers were donated to the aforementioned medical colleges for routine dissection studies to be performed by undergraduate students of medicine. Fractured sternums and those with gross pathology were excluded. The sternums within the study sample belonged to individuals of known sex (75 male and 40 female) and age (range: 25–40 years) from Maharashtra region of western India. The morphometric parameters of the sternum, namely, length of manubrium (distance from the suprasternal notch to the manubriosternal junction in the midline) [*M*], length of mesosternum (distance from the manubriosternal junction to the meso-xiphoid junction in the midline) [*B*] were measured in millimeters according to the technique described by Ashley<sup>6</sup> with the help of vernier calipers to the nearest millimeter.

The sternal index (manubrio-corpus index) was calculated for each sternum using the formula: Sternal index = (*M/B*) × 100. The data obtained were computed and analyzed with SPSS (Statistical Package for Social Sciences, version 10.0) computer software. Student's *t*-test was used to compare the sternal index derived for males and females. The level of significance was set at 0.05. The applicability of Hyrtl's law in sex determination of the sternum in the present sample was also analyzed.

### 3. Results and discussion

#### 3.1. Manubrio-corpus index/sternal index

Table 1 depicts the descriptive statistics for length of manubrium, mesosternum and sternal index. The sternal index for male sternums varied from 36.1 to 93.1 with a mean of 59.21, and that for female sternums varied from 36.3 to 88.1 with a mean of 63.31. In the present study, the mean sternal index value for females was significantly higher than that for males ( $p = 0.03$ ,  $t = -2.16$ ), similar to observations made in other studies.<sup>7–11</sup> Sternal index derived for the study sample has been compared with various other Indian

**Table 1**

Descriptive statistics: sternal measurements (mm) and sternal index in males and females

Parameter	Male ( <i>n</i> = 75)			Female ( <i>n</i> = 40)		
	Mean	SD	Range	Mean	SD	Range
Length of manubrium ( <i>M</i> )	51.99	4.96	43–70	44.88	5.26	32–57
Length of mesosternum ( <i>B</i> )	89.17	10.63	65–120	72.38	12.76	42–95
Sternal index	59.21*	09.85	36.1–93.1	63.31*	09.41	36.3–88.1

SD: Standard deviation.

\*  $p < 0.05$ ,  $t = -2.16$ .

**Table 2**

Comparison of sternal index with other Indian studies

Study	Gender	Bones ( <i>n</i> )	Range	Mean	SD	Overlapping values (%)
Narayan et al. [8]	Male	126	31.72–85.33	54.76	±9.94	–
	Female	27	44.33–80.00	58.98	±9.61	–
Jit et al. [9]	Male	312	35.00–94.00	55.53**	±9.57	99.68
	Female	88	32.00–88.00	61.80**	±10.62	98.86
Dahipale et al. [10]	Male	96	36.00–77.00	51.99**	±8.34	44.79
	Female	47	51.00–91.00	63.01**	±8.50	95.74
Present study	Male	75	36.13–93.06	59.21*	±9.85	97.33
	Female	40	36.26–88.10	63.31*	±9.41	100.00

SD: Standard deviation.

\*  $p < 0.05$ .

\*\*  $p < 0.001$ .

studies (Table 2). Mean sternal index values for males and females in the present study were higher when compared to other Indian studies<sup>8–10</sup> suggesting population differences in the sternal index and signifying the importance of application of indices on the population group from which they are derived. Although statistically significant sex differences are obvious, sternal index among males and females shows considerable overlapping. Distribution of male and female sternums for sternal index is shown in Table 3. More than 1/3rd males had sternal index of less than 55, while more than 1/3rd females had sternal index of more than 65. Forty-four percent males and 45% females fell in the 55–65 range. Our findings are similar to those reported by Jit et al.<sup>9</sup> who found statistical difference in the mean values despite a high percentage of cases falling within the range of opposite sex (99.68% in males and 98.86% in females).

#### 3.2. Applicability of Hyrtl's law

Various researchers have studied the applicability of Hyrtl's law.<sup>6,8–10,12,13</sup> When Hyrtl's law was applied, 14 male sternums and 38 female sternums in our study obeyed the law. The percentage of males obeying the Hyrtl's law (18.7%) is very less in comparison to other study groups, while in females it was 95% which is relatively higher than most of the other study groups. Comparative analysis of applicability of Hyrtl's law in different studies is shown in Table 4. It is apparent that the percentage of female sternums obeying the Hyrtl's law is significantly higher in Indian studies<sup>8–10</sup> when

**Table 3**

Distribution of male and female sternums for sternal index

Sternal index	Male		Female		Total	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
35–40	01	1.3	01	2.5	02	1.7
>40–45	01	1.3	00	0.0	01	0.9
>45–50	12	16.0	01	2.5	13	11.3
>50–55	12	16.0	04	10.0	16	13.9
>55–60	20	26.7	09	22.5	29	25.2
>60–65	13	17.3	09	22.5	22	19.1
>65–70	06	8.0	07	17.5	13	11.3
>70–75	06	8.0	06	15.0	12	10.4
>75–80	01	1.3	02	5.0	03	2.6
>80–85	02	2.7	00	0.0	02	1.7
>85	01	1.3	01	2.5	02	1.7
Total	75	100	40	100	115	100

**Table 4**

Applicability of Hyrtl's law

Study	Gender	Bones ( <i>n</i> )	Accuracy of Hyrtl's law (%)
Dwight [12]	Male	30	60.0
	Female	26	46.2
Dwight [13]	Male	142	59.1
	Female	86	60.4
Ashely [6]	Male	85	64.7
	Female	13	69.2
European	Male	378	52.9
	Female	171	69.3
Narayan et al. [8]	Male	126	34.1
	Female	27	81.5
Jit et al. [9]	Male	312	31.1
	Female	88	88.6
Dahipale et al. [10]	Male	96	52.2
	Female	47	100.0
Present study	Male	75	18.7
	Female	40	95.0

compared to African and European study groups,<sup>6,12,13</sup> while for male sternums it is relatively lower. This may be suggestive of racial differences in the sternal index, a fact that needs to be further explored and confirmed. However, since most of the sternums lie in the range of the opposite sex, the law when applied to an individual specimen may not be helpful in determining the sex.

#### 4. Conclusion

The study ascertains that

- Although statistically significant sex differences are observed in sternal index, sex determination can not be made conclusively from the sternal index in the Maharashtrian population of western India.
- Hyrtl's law cannot be applied to the sternums confined to the Maharashtrian population of western India.
- Sternal index varies for different population groups.

Similar studies are proposed on larger samples in different population groups where sternal index is not yet evaluated in attempting to determine sex of the sternum. As our study further confirms that the sternal index varies for different population groups, we propose that further studies on comparative samples may be helpful in ascertaining whether sternal index can be used to determine the race or a particular population.

#### Conflict of Interest

None declared.

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#### Ethical Approval

No ethical approval is needed as it is a short report.

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